

The nonlinear conjugate gradient method is an iterative method using the conjugacy property of the matrix to solve a nonlinear system of equations. Details of the method can be found in *Numerical Optimization*(Nocedal, J., & Wright, S. (2006). Numerical optimization. Springer Science & Business Media.).

[called by: [solvers](#).]

[calls: [packdof](#).]

Basic algorithm

The basic nonlinear conjugate gradient algorithm used in FOCUS is a hybrid of **Algorithm 5.4** and **Equation (5.49)** from *Numerical Optimization* and [Dai & Yuan](#). This version of conjugate gradient method converges globally, provided the line search satisfies the standard Wolfe conditions.

Our target function is $\chi^2(\mathbf{X})$, while \mathbf{X} is the variables vector. As we mentioned before, we can calculate the gradient $G(\mathbf{X}) = \frac{\partial \chi^2}{\partial \mathbf{X}}$ accurately with analytical expressions. The structure of the algorithm is as below.

```

k = 0: for initial  $\mathbf{X}_0$ , evaluate  $\chi^2(\mathbf{X}_0)$  and  $G(\mathbf{X}_0)$ ;  $p_0 = -G_0$ ;
while  $G_k > \epsilon$  :
 $\mathbf{X}_{k+1} = \mathbf{X}_k + \alpha_k p_k$  ( $\alpha_k$  satisfies strong Wolfe condition);
 $\beta_{k+1} = \frac{|G_{k+1}|^2}{(G_{k+1} - G_k)^T p_k}$ ;
 $p_{k+1} = -G_{k+1} + \beta_{k+1} p_k$  ;
 $k = k + 1$  ;
end(while)

```

The line search algorithm is applying the **Algorithm 3.5 & 3.6** in the book to satisfy the strong Wolfe conditions.

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[Focus subroutines](#);